

Final Report

“Exploring New Methods of Displaying Bit-Level Quality and Other Flags for MODIS Data”

Earth Science Technology Office

Award Number QRS-01-0015

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1. Background

The NASA Distributed Active Archive Center (DAAC) at the National Snow and Ice Data Center (NSIDC) archives and distributes snow and sea ice products derived from the MODerate resolution Imaging Spectroradiometer (MODIS) [1], [2] on board NASA's Terra and Aqua satellites. All MODIS standard products are in the Earth Observing System version of the Hierarchical Data Format (HDF-EOS). The MODIS science team has packed a wealth of information into each HDF-EOS file. In addition to the science data arrays containing the geophysical product, there are often pixel-level Quality Assurance arrays which are important for understanding and interpreting the science data.

Currently, researchers are limited in their ability to access and decode information stored as individual bits in many of the MODIS science products. Commercial and public domain utilities give users access, in varying degrees, to the elements inside MODIS HDF-EOS files. However, when attempting to visualize the data, users are confronted with the fact that many of the elements actually represent eight different 1-bit arrays packed into a single byte array.

This project addressed the need for researchers to access bit-level information inside MODIS data files. In an previous NASA-funded project (ESDIS Prototype ID 50.0) we developed a visualization tool tailored to polar gridded HDF-EOS data sets. This tool, called the Polar HDF-EOS Data Imaging and Subsetting (PHDIS) Tool, allows researchers to access, geolocate, visualize, and subset data that originate from different sources and have different spatial resolutions but which are placed on a common polar grid. The bit-level visualization function developed under this project was added to PHDIS, resulting in a versatile tool that serves a variety of needs. We call this the EOS Imaging Tool.

1.1. Example - MODIS Cloud Mask

As with many of the MODIS land products, the snow product uses as input other MODIS products, particularly the cloud mask [3]. Some shortcomings in the snow product have been traced to the cloud mask; therefore, is it very useful to be able to examine the corresponding cloud mask product when diagnosing the snow product. The cloud mask information (processing path and results of individual cloud tests) is conveyed in a 48-bit array that cannot be interpreted by simple visualization. An image made from the first 8-bits of the cloud mask has 256 possible colors (Fig. 1), and is nearly useless for determining which of the 8 bits are on and off for any given pixel.



Figure 1. Visualization of first byte of MODIS cloud mask for a scene over western North America. This byte contains 2 bits with summary cloud probability information, combined with surface type information and a bit indicating where sunglint is possible.

1.2. Goal

The goal of this project was to develop a method of displaying one or more bit-level elements simultaneously with a visual representation of a geophysical data field in such a way that the spatial relationship between the various fields is preserved. This is the equivalent to displaying maps of several different variables superimposed upon one another. We wanted the interface to be intuitive and easy to use. Another goal was to have the software capable of working with a wide variety of EOS products. We also wanted the software to be available for all common platforms.

1.3. Approach

To address the goal of platform independence we chose to write the software in Interactive Data Language (IDL) from Research Systems, Inc. An advantage to using IDL is the large variety of utilities and code segments that have been placed in the public domain. This project reused and adapted some code from Fanning Software Consulting, Ft. Collins, CO (www.dfanning.com).

The PI surveyed current data visualization projects via the web, conference proceedings, and direct contact with groups doing similar work. At the 2002 IEEE International Geoscience and Remote Sensing Symposium (IGARSS'02) in Toronto the PI listened with interest to a paper titled "Information Visualization of High-Dimensional Satellite Datasets." However, the approach described, involving animated stick figures with different gestures and rates of motion conveying different variables and their magnitudes, was deemed inappropriate for the purposes of this study. The primary reason was that the density of information in a typical MODIS scene ($2708 \times 4060 = 11$ million pixels at 500m ground resolution) was too great to make this method practical.

The approach we settled on was to use the bit-level information to create a mask which overlays a "background" image. This background can be imagery (e.g. channel radiance), a geophysical variable (e.g. snow), or null (i.e. black, which allows unaltered viewing of the mask by itself). The opacity of the bit layer mask is variable, allowing the user adjust the colors of the mask that "tint" the background image.

We allow the user to choose up to 4 separate bits to display in the mask. These 4 bits vary independently, yielding 16 different combinations which are represented by 16 distinct colors in the mask.

2. Accomplishments

2.1. Tool Description

We first developed a prototype of the bit-viewing functionality as stand-alone code working on data arrays that had been extracted from HDF-EOS files and converted to flat binary files. This allowed us to explore various methods of visualization and the types and layout of controls in the graphical user interface before attempting to integrate this functionality into the earlier prototype.

In this code a user first selects the files and data fields to be examined. Fields are designated for either "background" or "bit-viewing." Also, the user may select which field to use for the "navigation" window. After these selections are made a navigation window is drawn displaying an image of the field chosen for navigation. The field is sub-sampled so that the entire scene is visible on the screen.

A user draws a box in the navigation window indicating the region to be examined. The tool then displays, at a user-selected magnification, up to four different bits of the data array selected for bit viewing in that box. Fig. 2 gives an example where the results of 4 cloud mask tests are displayed over a black background. This is the mode in which it is easiest to match display colors with the color legend.

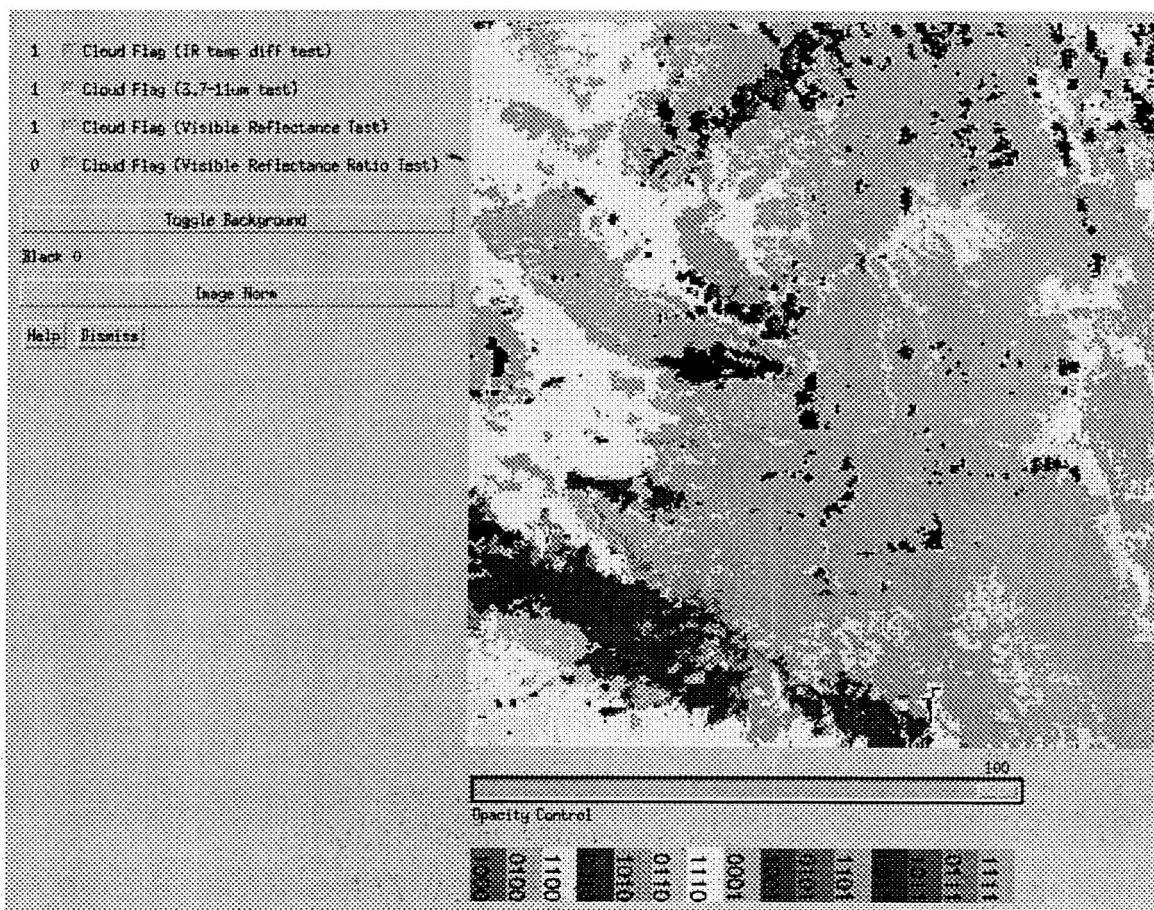


Figure 2. Display of four cloud mask bits.

In the upper left of the window (Fig. 2) are check boxes allowing the user to select which of the four bits (selectable on a previous screen) to display. Names for these bits are contained in a look-up table for common MODIS products. This information is not readily available in the internal metadata of the files. For those products not contained in the LUT, the bits are simply labeled, ByteNBitM.

To the left of the check boxes a user can read the state of each bit as the cursor is passed over the image. The "Toggle" bar below the boxes allows the user to toggle between the background images (e.g. snow cover or radiance data), or black. The "Image Norm" bar performs an image normalization, which is useful for radiance data displayed with a linear grey scale. "Help" brings up a file describing the main program functions, and "Dismiss" closes the window.

The slider at the bottom of the screen allows the user to control the opacity of the bit layer. In this way the bit layer can be viewed as "coloring" the background image. In the places where all the selected bits are "off," the background image is unaltered.

The prototype version of this tool has already proven to be quite valuable in research leading to improvements in the MODIS product suite.

2.2. Integration with Previous Prototype

With the functional prototype of the bit-viewing code in hand, we began considering ways to integrate it into the Polar HDF-EOS Data Imaging and Subsetting (PHDIS) Tool. We decided to have two branches to the integrated tool: one for viewing data in a georeferenced context, and another for bit-level viewing. The file selection, metadata viewing and field selection portions of the PHDIS code would be used for both viewing methods. We decided against bit-viewing in a georeferenced context because in order to view swath data in a georeferenced context the data must first be gridded, which can be computationally intensive, slowing the display process. Also, gridding may alter data products in ways that make comparisons between different products more difficult.

A flowchart for the EOS Imaging Tool is presented in Fig. 3.

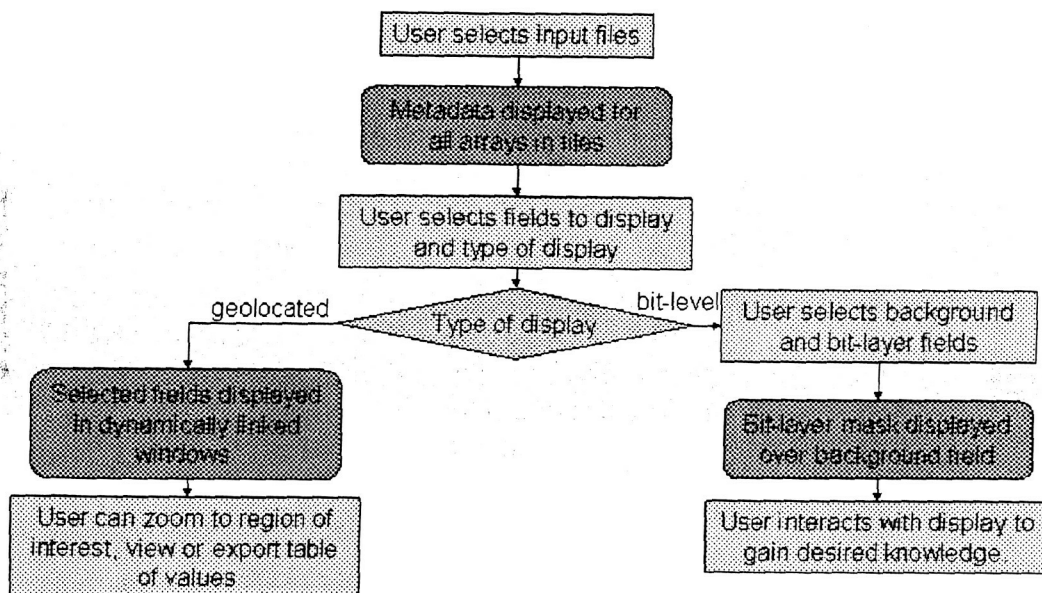


Figure 3 Flowchart for usage of the EOS Imaging Tool.

Each time a user selects a data field from the list of available fields in each file, a user then chooses to view that field in either the georeferenced or bit-level contexts. Both types of displays can be present on the desktop at the same time.

2.3. Presentations

An early version of the tool (working title: “zoombytes”) was described at the Science Data Processing Workshop 2002 held in Greenbelt, Maryland, Feb. 27-28 [4]. A later version of the tool was described at the Earth Science Technology Conference, June 11-13, 2002, in Pasadena, California [5]. A beta version of the integrated tool was demonstrated at the HDF-EOS Workshop VI held in San Francisco: December 4-5, 2002. A paper was presented at the Fall AGU in San Francisco, December 6-10, 2002, describing the tool [6].

2.4. Testing

The EOS Imaging Tool has been tested on the following platforms:

Architecture	Operating System
PC	Linux (SuSE)
PC	Windows 2000
SGI	IRIX (Unix)
Sun	SunOS (Unix)

Table 1. Platforms and operating systems under which the EOS Imaging Tool has been tested.

The data products which have successfully read and viewed with EOS Imaging Tool are given below:

Product Type	Product ShortName
MODIS Radiance	MOD021KM, MOD02HKM, MOD02QKM
MODIS Snow & Ice	MOD10_L2, MOD10A1, MOD29, MOD29P1D/N
MODIS Atmosphere	MOD04_L2, MOD05_L2, MOD06_L2, MOD35_L2
MODIS Vegetation, LAI/FPAR	MOD13A1, MOD15A1
MODIS Surface Reflectance	MOD09A1
AMSR Snow	AE_DySno, AE_MoSno
TOVS Pathfinder	TPP
SSM/I	Brightness temps, NISE

Table 2. Data products that have been tested with the EOS Imaging Tool.

3. TRL assessment

The entry Technology Readiness Level (TRL) for this project was placed at 3. The exit TRL we place at 6, since a prototype has been demonstrated in relevant environment on full-scale realistic problems, engineering feasibility has been fully demonstrated in actual system application, and limited documentation is available.

To bring the Prototype to a TRL of 7, i.e. to make it ready for "Deployment in operational environment," the following would be required:

- More testing and bug fixes
- Develop a plan for ongoing user support and software maintenance
- Develop and maintain a distribution and support web site

Optionally, to make the software available to users without IDL, we would have to purchase embedded IDL licenses.

4. References

[1] Justice, C.O., and 22 others, "The Moderate Resolution Imaging Spectroradiometer (MODIS): land remote sensing for global change research," IEEE Trans. on Geosci. and Rem. Sens., 36(4):1228-1249, 1998.

[2] D.K. Hall, G.A. Riggs and V.V. Salomonson, "Development of methods for mapping global snow cover using Moderate Resolution Imaging Spectroradiometer (MODIS) data," Rem. Sens. of Environ., 54:127-140, 1995.

[3] Ackerman, S. A., Strabala, K. I., Menzel, W. P., Frey, R. A., Moeller, C. C., Gumley, L. E., "Discriminating clear sky from clouds with MODIS," Journal of Geophysical Research, 103, 1998.

[4] Khalsa, S.J.S., "Facilitating Access to EOS Data at the NSIDC DAAC," Science Data Processing Workshop 2002, Greenbelt MD, 26-28 Feb 2002.

[5] Weaver, R. and Khalsa, S.J.S., "Extracting and Viewing Bit-Level Metadata in EOS Files," Earth Science Technology Conference - 2002, Pasadena CA, 11-13 June 2002.

[6] Khalsa, S.J.S., Savoie, M., and Weaver, R., "The EOS Imaging Tool," 2002 Fall Meeting of the American Geophysical Union, San Francisco, California, 6-10 December, 2002.

5. Acknowledgements

The coding for this project was performed by Matt Savoie. In addition, he contributed many useful ideas throughout the evolution of the project.